Microbially-Facilitated Remediation of Metals and Radionuclides

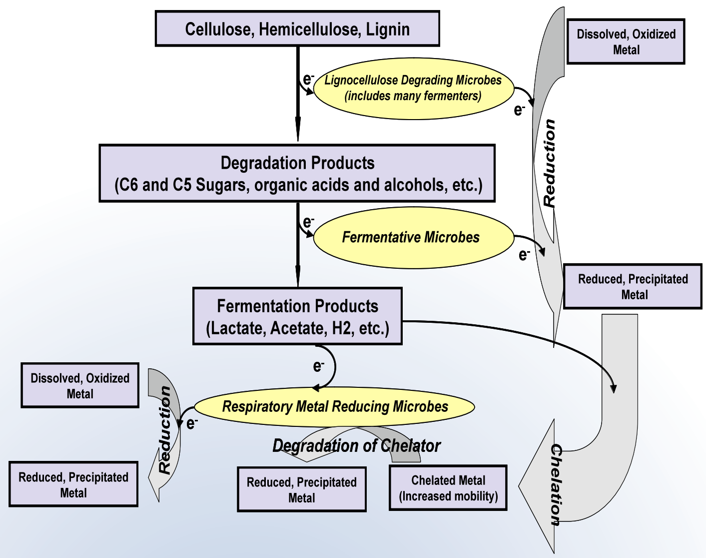
Numerous waste sites across the U.S. Department of Energy complex are contaminated with metals and radionuclides. These metals and radionuclides are often the primary drivers for remedial activities at these sites. In situ methods for the remediation of metals and radionuclides are currently being developed. Fate and transport of metals and radionuclides can be directly or indirectly affected by the activity of microbes. At INL, research has focused on microbial reduction of Cr(VI) and of U(VI), which can lead to nontoxic and immobile forms. In addition, INL researchers have investigated the microbially-facilitated precipitation of minerals that can sequester radionuclides such as Sr-90 and U(VI) through coprecipitation. Considerable progress has been made in these two areas, as discussed below.

Focus on microbial metal reduction

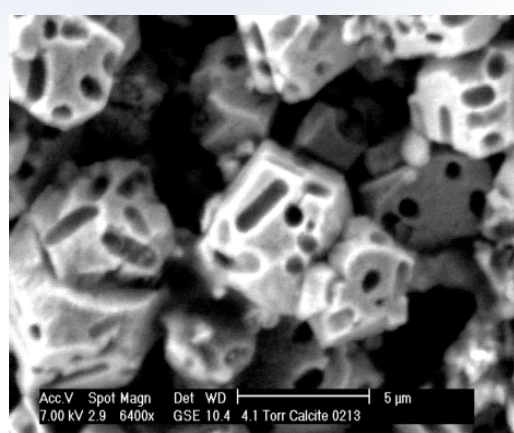
Hexavalent chromium [Cr(VI)] and uranium [U(VI)] contamination occur in groundwater and soil at more DOE waste sites than any other category of contaminant. Toxicity and mobility of these contaminants is highly dependent on their valence state; research has demonstrated that bacteria indigenous to soils can, as part of their normal respiratory metabolism, reduce metals and radionuclides such as Cr(VI) and U(VI). This process is important to understand because reduction of these contaminants decreases both mobility and toxicity.

Our recent research has demonstrated that a cellulolytic and fermentative bacteria, a *Cellulomonas spp.* isolated from Hanford sediments, can reduce and precipitate metals and radionuclides, such as Cr(VI) and U(VI), in the presence of sugars such as xylose and glucose, while producing short chain organic acids such as lactate, acetate and formate. These fermentation products can influence the mobility of metals and radionuclides through chelation (resulting in increased mobility) or by acting as carbon and energy sources for other metal and radionuclide reducing bacteria (potentially resulting in decreased contaminant mobility). Our current research, sponsored by the DOE Office of Science, is directed towards better understanding

Continued next page



Schematic showing the hypothesized central role of fermentation bacteria like Cellulomonas spp. in subsurface metal and radionuclide reduction.



Calcite precipitated by urea hydrolizing bacteria.

Continued from previous page`

the role of fermentative bacteria in metal and radionuclide reduction. This research is designed to show that the little studied fermentative bacteria actually may be central in controlling rates of microbial metal and radionuclide reduction in many subsurface environments.

Microbially-mediated coprecipitation

Geochemical and microbiological approaches have been combined to resolve metal and radionuclide contamination issues. Microbial activity can indirectly affect the mobility of metals and radionuclides through coprecipitation of these contaminants in minerals such as calcium carbonate or calcium phosphates.

We are currently studying the potential for urea hydrolyzing organisms to accelerate calcite precipitation and coprecipitation of contaminants such as Sr-90. Laboratory studies have indicated the promise of this approach, and we are currently conducting field trials.

More recently, we have begun investigating whether microbial hydrolysis of organic phosphate compounds can immobilize metals such as U(VI) and Sr-90 through coprecipitation in phosphate minerals. With both coprecipitation approaches, an important goal is demonstrating that the remediation is sustainable over the long-term. Both coprecipitation research efforts are also sponsored by the DOE Office of Science.

Selected Publications/Presentations/Patents

Viamajala, S., W. A. Smith, R. K. Sani, W. A. Apel, J. N. Petersen, A. L. Neal, F. F. Roberto, D. T. Newby, and B. M. Peyton. 2007. “Isolation and characterization of Cr(VI) reducing Cellulomonas spp. from subsurface soils: Implication for long-term chromate reduction.” Biores. Technol. 98:612-622.

Tyler, T. L., Sheridan, P. P., Watwood, M. E., Fujita, Y. and F. S. Colwell. 2007. “Design and validation of polymerase chain reaction primers based on ureC for environmental detection of urea-hydrolyzing bacteria.” Geomicrobiology Journal, 24(3), 353-364.

Horton, R. N., W. A. Apel, V. S. Thompson, and P. P. Sheridan. 2006. “Low temperature reduction of hexavalent chromium by a microbial enrichment consortium and a novel strain of Arthrobacter aurescens.” BMC Microbiol. 6: Art. No. 5.

Freeman, S. A., Reed, D. W. and Y. Fujita. 2006. “Testing the Specificity of Primers to Environmental Ammonia Monooxygenase (amoA) Genes in Groundwater Treated with Urea to Promote Calcite Precipitation.” Journal of Undergraduate Research, vol. VI, 114-118.

Colwell, F.S., R.W. Smith, F.G. Ferris, A.-L. Reysenbach, Y. Fujita, T.L. Tyler, J.L. Taylor, A. Banta, M.E. Delwiche, T. McLing, and M.E. Watwood. 2005. “Microbially-mediated subsurface calcite precipitation for removal of hazardous divalent cations: Microbial activity, molecular biology, and modeling.” Subsurface Contamination Remediation: Accomplishments of the Environmental Mgmt. Science Program. American Chemical Society Symposium Series 904. E. Berkey and T. Zachry, American Chemical Society: 117-137.

Lee B. D., Walton, M. R., and Megio, J. L. 2005. “Biological and Chemical Interactions with U(VI) During Anaerobic Enrichment in the Presence of Iron Oxide Coated Quartz.” Wat. Res. 39: 4363-4374.

Fujita, Y., G.D. Redden, J.A. Ingram, M.M. Cortez, and R.W. Smith. 2004. “Strontium incorporation into calcite generated by bacterial ureolysis.” Geochimica et Cosmochimica Acta, 68, 3261.

Ferris, F. G., V. Phoenix, Y. Fujita, and R.W. Smith. 2004. “Kinetics of Calcite Precipitation Induced by Ureolytic Bacteria at 10 to 20°C in Artificial Groundwater.” Geochimica et Cosmochimica Acta, 68, 1701.

Smith, W. A., W. A. Apel, J. N. Petersen, and B. M. Peyton. 2002. “Effect of carbon and energy source on bacterial chromate reduction.” Biorem. J. 6(1):1-11.

Sani, R. K., B. M. Peyton, W. A. Smith, W. A. Apel, and J. N. Petersen. 2002. “Dissimlatory reduction of Cr(VI), Fe(III), and U(VI) by Cellulomonas isolates.” Appl. Microbiol. Biotechnol. 60:192-199.

For more information

Technical Contacts

William Apel, PH.D.
(208) 526-1873
William.Apel@inl.gov

Yoshiko Fujita, Ph.D.
(208) 526-1242
Yoshiko.Fujita@inl.gov

Brady Lee, M.S.
(208) 526-0981
Brady.Lee@inl.gov

Management Contact

Don Maiers
(208) 526-6991
Donald.Maiers@inl.gov

www.inl.gov/biologicalsystems

A U.S. Department of Energy National Laboratory

08-GA50094-23-R5